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Erosion Studies and Rehabilitation of Beach along West Coast of India

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Abstract. The west cost of India from Kannyakumari in Tamilnadu to Thengapattinam bordering Kerala at Thengapattinam is oriented in the east-west direction compared to other two boundaries which are oriented along north-south direction. In these coastal areas the protection measures executed are frequently getting damaged mainly due to unprecedented waves and south west monsoon waves. Hence it was felt to do a detailed study by taking field profiles at selected locations, design of sections and model studies This calls for a proper understanding of the wave hydrodynamics prevailing as it plays a major role in formation of beaches. The stretch is having high tourist potential and it is important to prevent the erosion of beach and stabilize the coast. Field observations were taken and desk studies were made. Based on the studies suitable model studies were carried out and remedial measures were carried out at one site. Post monitoring of the project was done and based on the post monitoring it was inferred that project was a success. The details are explained in the paper.

1. Introduction
The coastal reach from Kannykumari in Tamilnadu to Neerodi near Kerala is a thickly populated one. Fishing is the sole bread and butter of the coastal community. The coast undergoes tremendous erosion during south west monsoon from June to September resulting heavy erosion of land and infrastructure. Hence studies were made which consists of field visit, desk studies, studies on wave dynamics and remedial measures.

2. Study Area
The total coastline divided into two reaches, based on the field visit (Figure 1). The details of the geometry as inferred from the bathymetric charts indicates reach 1 is from Muttom to Thengapattanam. The coastline is oriented in 125^0 N along east-west direction. The height of the coast is increasing along the reach and it has protrusions. Beaches are observed at selected places along the stretch. The foreshore slope is about 20 in 1000 and it becomes steeper near Thengapattinam. The second reach is from Thengapattinam to Neerody. The value of foreshore slope assessed as 33 in 1000 near Neerodi (Figure 1).

Figure 1. Study Reach

The coastline is oriented in 128^0 N along east-west direction. No beaches are observed at selected places along the stretch. The foreshore slope is about 35 in 1000. The deep foreshore slope results in high wave run up and erosion of armour layer. The coastal road is prone to direct wave action is totally damaged. As a crises management seawalls are constructed to protect the properties on land. The seawall sections are unstable along the places where foreshore slope increases and are in a disturbed state (Figure 2 and Figure 3).

Figure 2. Sliding of existing seawall

Figure 3. Erosion of coastal road

The seawalls are found to give some success in places where the foreshore slope is shallow (Reach1 and Part of reach 2) due to good beach formations. The seawalls, which were constructed earlier, are totally eroded.

3. Desk Studies

The studies include the data on availability of historical shoreline data. Satellite imageries are the best suited sources. The imageries of the coast at Neerodi and Mandaikkadu during 2001 and 2015 were collected from Google earth. The orientation of beaches adjacent to the above coast were identified for both years; on overlapping the imageries of two years it was found that along the coast of Neerodi the shoreline was eroded by about 40 m and adjacent to the coast of Mandaikkadu it was eroded by about 10 m over a period of 15 years (Figure 4).
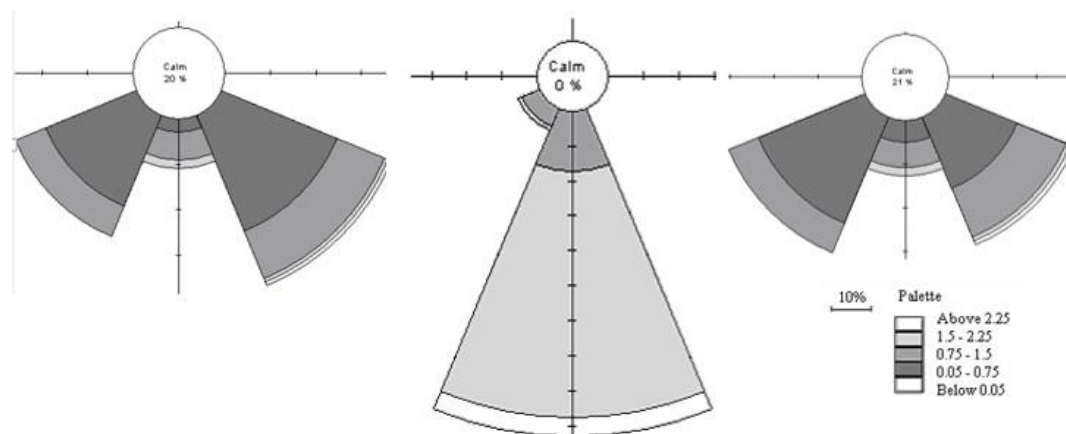

Figure 4. Erosion along Neerodi

Figure 5. Wave rose diagram

4. Wave Climate

Assessment of wave climate is an important task for any coastal engineering study. Usually the nearest deep water buoy data is collected and the near shore wave climate is derived. Based on the nearshore wave climate, assessment of beach formations carried out. In the present study, the wave data was not available for all locations and except at selected location. In the present work the available data analyses carried out as per Suresh and Sundar [1]. The numerical model MIKE 21 by Danish Hydraulic Institute,

Denmark [2] was adopted. The wave data for the coast is available from Indian National Centre for Ocean Information (INCOIS) website [3]. The wave rider buoy for Colachel for the year 2018 was collected, analyzed and furnished vide table 1 below. The average values were arrived after the analyses of wave data. The wave heights derived based on analyses indicate it is low in non-monsoon and northeast monsoon. The south west monsoon waves are found to be high and maximum wave heights of 1 to 2.m was observed. There were occasional observations of maximum wave heights up to 4 m during the south monsoon (Figure 5).

5. The Protection measures
Usually protection measures adopted in India are seawalls and groins. The seawalls will protect the structures behind whereas the groins are capable of creating beaches. Along the coast of Mandaikkadu a groin field consisting of six short groins installed after detailed studies as described by Sundaravadivelu et al [4]. The protection measures consist of a groin field with six groins. The commencement of the groin field is from the coast adjacent to Church. It consists of six groins G1, G2, G3, G4, G5 & G6 of length 65 m, 81 m, 90 m, 60 m, 63 m & 60 m respectively. The corresponding depth at which the above groins terminate are (-) 2.0 m, (-) 3.0 m, (-) 3.0 m, (-) 2.0 m, (-) 2.0 m and (-) 2.0 *m*. The spacing between the groins G1 to G6 are 100 m, 150 m, 150 m, 150 m and 100 m respectively (Figure 6).
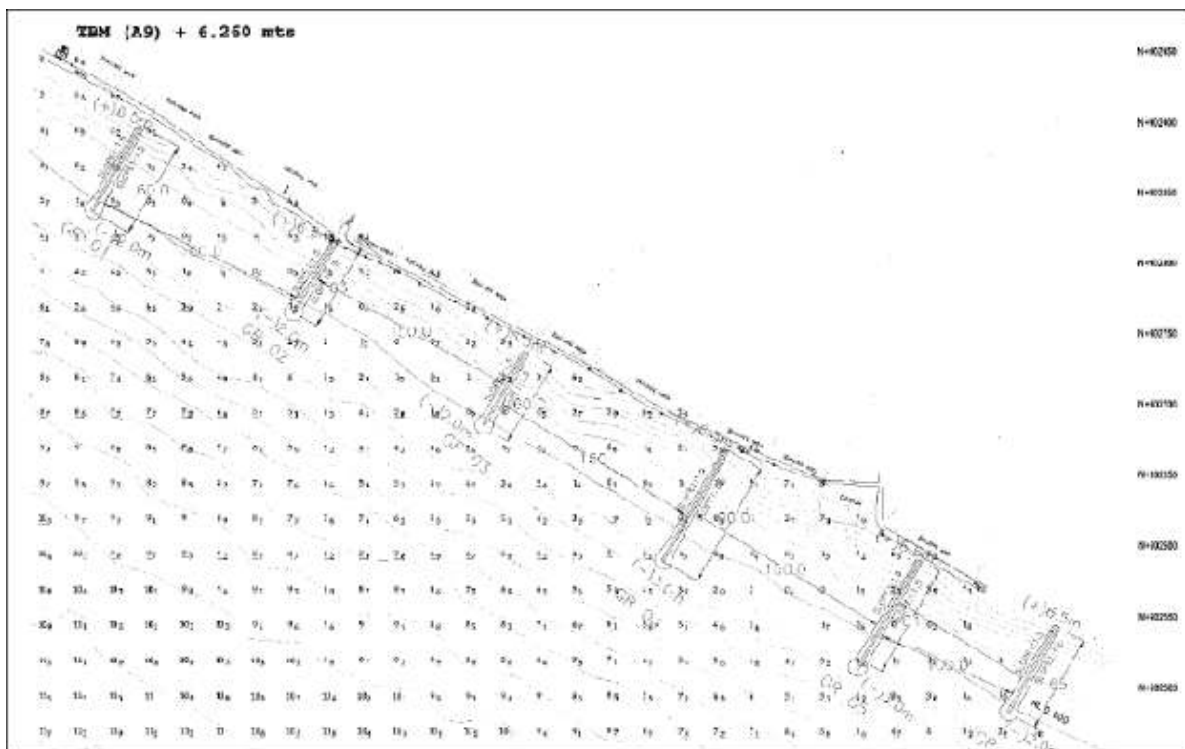

Figure 6. Proposed groin field along Mandaikkadu

6. Numerical modeling of shoreline evolution
The impact of groins on the present shoreline was studied. The predictions indicate that groins will be by- passed in one year after construction. The construction of the groins was completed by the year 2018. Post monitoring of shoreline was carried out. The beach formation up to 80 m was noticed by January 2019. These predictions are as per Kraus and Harikai [5]. The procedures adopted by Suresh & Sundar [6] are adopted for the prediction of shoreline evolution in the presence of shore connected structures. The formulated model basically relates the change in shoreline orientation

with the rate of sediment material transported along the beach. The governing equation is given below.

$$(b+D_c) \, \partial y / \partial t = - (\partial Q / \partial x + q(x) \tag{1}$$

y = Position of shoreline seaward and a function of 'x' measured along shore and time 't'.

b = Height of berm

D_c = Limit of active transport (Hallerimeter [7])

Q = wave induced sediment

Q(x) = quantity of sediment added

In the present case, the term q(x) is not considered; as it represents sediment added from rivers. The long-term shoreline evolution of shoreline because of the introduction of groin field is carried out. This is done with a view to study the effect of groins and whether any adverse changes will be happening. The wave induced sediment component is an important parameter and is carried out based on empirical expressions. Usually the expressions correlates the rate of alongshore transport 'Q' with wave energy flux 'E' along the alongshore direction. The expressions adopted for alongshore transport is explained below. The energy flux Pl along the alongshore direction is given as

$$P1 = E_b \, C_{gb} \, \sin\alpha_b \, {}_b \cos\alpha_b \tag{2}$$

The energy density of wave $E_b = (1/8) \, \rho \, g \, H_b^2$, C_{gb} denotes the wave group velocity; α_b is the angle of wave propagation direction with reference to normal to the shoreline. The suffix 'b' refers to the corresponding variables at breaker point. The breaker angle and breaker wave height H_b is calculated adopting Snell's law.

ρ = Mass density of sea water
G = Gravitational constant

$$K_r = (\cos\alpha_o / \cos\alpha_b)^{0.5} \tag{3}$$

K_r = Refraction coefficient

α_o, α_b = the wave angles at breaker depth and deep water respectively with respect to shore normal as described in Figure 7.

When the coastal modelling point under consideration in the diffraction region, 'Kr' is replaced by 'Kr Kd' and Kd is the diffraction coefficient. Then the alongshore transport is calculated as below.

$$Q = A \, K_r^2 \, K_d^2 \, \sin\alpha_b \, \cos\alpha_b \tag{4}$$

'A' is called transport parameter calculated as per Van Rijn [8] equation as below

$$Q = 40 \, K_{swell} \, K_{grain} \, K_{slope} \, (H_b)^3 \sin(2\alpha_b) \tag{5}$$

Q = Alongshore sediment transport (kg/s),
T_P= Peak period, Swell correction factor, K_{swell} = TP/6, D50 = Particle size (mm),
K_{grain}= Particle size correction factor = 0.20/D50, K_{slope}= Slope correction factor = $(\tan\beta/0.01)^{0.5}$
The transport expression is converted in to volumetric units

$$Q = A \, (K_{swell} \, K_{grain} K_{slope}) \, (H_{s,}b_r)^3 \sin(2\alpha_b) \tag{6}$$

When the modelling point is not in the the diffraction coefficient K_d is taken as 1.
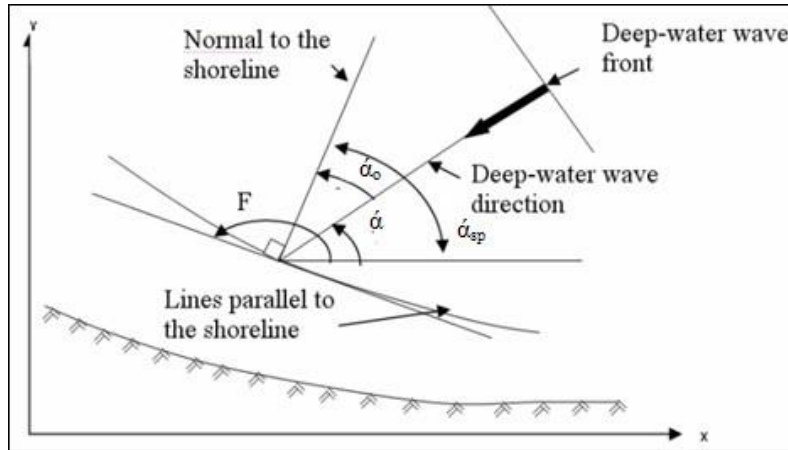

Figure 7. Details of wave angles

If the point is in the geometric shadow region of breakwater / groin, diffraction coefficients adopted as per Dean and Dalrymple [9]. The shoreline variable is made non-dimensional and divided in to 'N' grid point at equal non-dimensional interval 'δx. Then the shoreline changes over non-dimensional time 'δt' are calculated as adopting Crank – Nicholson finite difference scheme. The schematic diagram for finite difference adopted is shown in Figure 8.
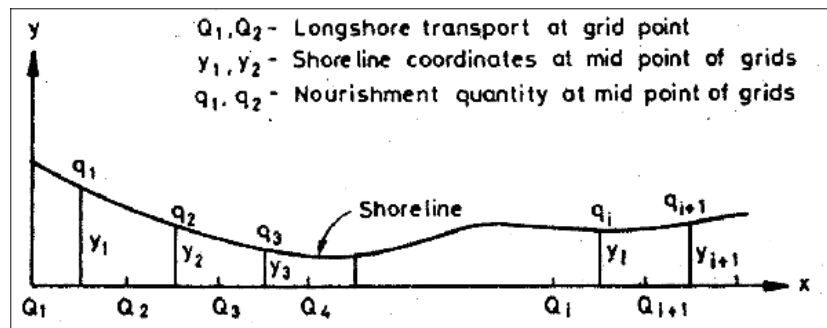

Figure 8. Model scheme diagram

The sample of two-layer groin cross section with a base layer was proposed at (-) 3.0 m water depth and details are shown vide Figure 9.
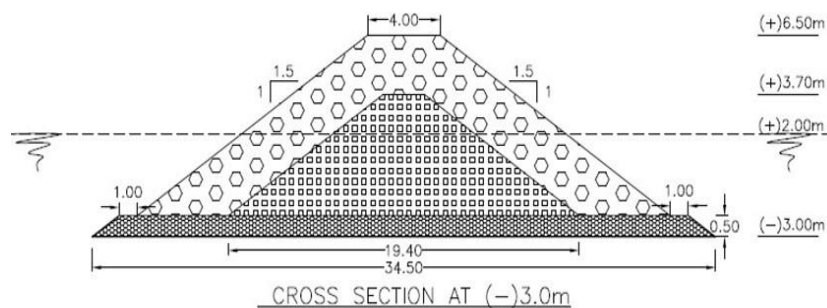

Figure 9. Cross section of the groin

Based on the above model description it was predicated that the beaches will form for the entire stretch of groin field. The structural design of the groin carried out based on the existing bathymetry.

7. Results and discussion

The project of coastal defense work was well planned after detailed studies and field observations. The wave data from INCOIS web site was adopted for initial planning. The project completed in 2018. The post observations indicate good beach formations. The details are furnished vide Figure 10 and Figure 11.

Figure 10. Beach formation along road which was eroded early

Figure 11. Creation of new recreation beach

8. Conclusions

The west coast of stretch from Tamil Nadu to Kerala is subjected to heavy wave energy dissipation during south west monsoon resulting in heavy erosion. The coastal protection measures in the form of short groin field results in good beach formation. The beaches in turn protect the existing roads and land by reducing the energy of waves during monsoon. The predicted and observed observations are nearly matching. Hence such protection measures can be adopted along such eroded stretch after sufficient studies.

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